ARIDITY, RISK CLIMATIC PHENOMENON IN DANUBE DELTA

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Abstract
Aridity is a major permanent risk for the climate of Danube Delta territory. Water resources and its quality are declining, and this is a severely limiting factor for both Danube Delta and the world, particularly with increasing aridity due to global warming predicted by some climate scenarios. Knowledge of aridity is also necessary to explain the characteristics of the geographical landscape for the rational use of water resources. Definition and characterization of aridity as intensity were done by several methods and indicators, starting with Lang's rain factor (1920), continuing with De Martonne's aridity index (1926), Thornthwaite's aridity index (1948), moisture deficit and ending with the UNESCO aridity index (1979). De Martonne's aridity index (1926) was recently amended by Murai and Hund (1991) to match the classification of vegetation in the world, but its use in the international literature has not been implemented so far. Danube Delta 's aridity is highlighted by all climatic aridity indices presented above; additional indicators can also be used. Increasing aridity in Danube Delta due to global warming is a real hazard, with the threat of desertification.

Keywords: *Danube Delta , aridity, climatic risk, desertification*

INTRODUCTION

Koppen's climate classification (1936), a Russian-born German climatologist (1846-1940), distinguished, inter alia, the major type of dry climate, rank 1, denoted with a capital letter B. The degree of climate dryness is the dry climate splitting criterion, marked by uppercase letters:

-S, Steppe (Steppe) and W for desert (Wüste)

-BS, steppe subtype, semiarid, is spread among others in southern Africa, in Spain, in the south-east of our country and the Romanian Black Sea coast, Mexico, Iran, etc., being characterized by grassy vegetation, often thorny, succulent, with small size. It covers approximately 14% of the Earth's surface. It receives more rain than the deserts (BW), both from the convergence inter tropical air, and from cyclones formed at median latitudes. To differentiate latitudinal semi-arid regions, the letter *h* is used additionally for the subtropical areas (BSh) and the letter *k* for those at median latitudes (BSk).

-BW, desert subtype is found in Patagonia, the Sahara, within the Arabian Peninsula, Turkmenistan, the Aral and Caspian region, the central part of Australia, etc. This subtype is sparsely grassy with discontinuous herbaceous vegetation, xerophytic and very poor, located in relatively moist areas of the desert. The oases due to the presence of ground water at the surface are an intrazonal exception of this subtype. Danube Delta fits in the BSk subtype within the Koppen climatic classification. What follows are the indicators that characterize aridity and their geographical distribution on the territory of Danube Delta .

For the preparation of this study we used climate data recorded between 1965-2005 from 9 weather stations figure 1.

Fig. 1. The location of weather stations and rainfall stations in Danube Delta used for the study of aridity

RESULTS AND DISCUSSIONS

The modern approach to the phenomenon of aridity in Danube Delta
1. De Martonne aridity index

Early studies on aridity in Danube Delta were made by Ioan (1929), and continued afterwards by several other authors, including Cernescu (1961), Berbecel (1984), and others.

A suggestive indicator for the characterization of the aridity index is De Martonne's (I_{ar-DM}), described by the formula:

$$I_{ar-DM} = P/(Tm + 10)$$

where: P = total annual precipitation and Tm = mean annual temperature. The denominator contains additionally the value of 10°C to produce positive results in regions with negative average annual temperatures, such as mountainous regions or deserts from median latitudes. This indicator was introduced by De Martonne (1926) to characterize the climate, and was subsequently used in the characterization of soil hydrologic regime, including in our country. In general, low values of I_{ar-DM} show dry conditions, while higher values show wet conditions. Table 1 presents De Martonne's climatic classification (1926) according to the I_{ar-DM} indicator.

Table 1 Climatic classification according to De Martonne (1926)

Type of climate	I_{ar-DM}
Very dry = desert (arid)	0-5
Dry = steppe, semiarid (semi desert)	5-15 (5-12)
Semi-dry (dry sub-humid)	15-20
Mildly wet (moist sub-humid)	20-30
Wed (wet)	30-60
Very wet (humid)	over 60

I_{ar-DM} - annual average in Danube Delta (1965-2005). The spatial distribution of De Martonne's aridity index (I_{ar-DM}) annually shows that Danube Delta has a high variability. In Danube Delta, I_{ar-DM} is below 20 (15-20), with small areas and lower values (below 15), figure 2.

This region, with pronounced aridity, has a specific agricultural profile, mainly cereals, being generally associated with the development of grapevine culture and thermophilic fruit trees, such as apricot and peach. High-yield agriculture cannot be done here now without the application of irrigation.

According to De Martonne's global classification where even deserts are considered (with values between 0-5, table 1), the I_{ar-DM} values from most of the territory used for agriculture in Danube Delta place it in the semi-arid class (15 to 20).

Monthly I_{ar-DM} values during the growing season

Fig. 2 *Territorial distribution of De Martonnne's annual aridity index (I_{ar-DM} mm/⁰C) in Dobrudja (1965-2005)*

De Martonne's aridity indexes were treated as monthly values for Dobrudja, brought to annual level with the relationship below, where p and t define the monthly values of rainfall sums, respectively of average temperature so that they can be placed in the classes that characterize aridity and could be compared among themselves. Monthly $I_{ar-DM} = 12 \, p / (t + 10)$.

There is an altitude layering for the values of monthly- I_{ar-DM}, starting with April and ending with October. All these indices increase slightly from April to June and then decrease slowly to September, at which point they begin to increase according to the variation of the constituent climatic elements.

2. Reference evapotranspiration (potential) – ET_o

Since the following terms use ET_o in their definition, a brief definition will be given as well as the established methods for calculating ET_o.

Evapotranspiration (ET, mm) is a complex process resulting from the combination of evaporation and plant transpiration.

Evaporation occurs due to the absorption of solar energy by water, having a particular influence, in addition to radiation, air temperature, air humidity and wind speed. By evaporation, the liquid water from oceans and seas, rivers, lakes, soils and rocks, from moist vegetation, etc. is transformed into vapor and removed from the surface by evaporation into the atmosphere.

The driving force that removes water vapor from the evaporation surface is the difference between the potential (pressure) of water vapor from the evaporation surface and the pressure of the surrounding atmosphere, which gradually becomes saturated with vapor. Thus, the evaporation is reduced and even stops to total saturation of the air. If the saturated air is removed from the evaporation surface by wind, then the process continues, this pressure difference controlling its intensity.

When the evaporation surface is not water from aquatic surfaces but water from the soil or rocks, then other factors such as water quantity or potential, proximity or remoteness of groundwater and/or the presence of the capillary fringe and plants shade intervene and influence this process. Where the porous soil environment can provide continuous water vapor supply into the atmosphere, the evaporation process is controlled only by atmospheric conditions. Otherwise, the availability of water in the porous environment reduces evaporation and may even stop it as the soil or rocks dry up at values equivalent to air drying or the hygroscopic coefficient.

Perspiration is also a process of water evaporation from plant tissues, from leaves through their openings - stomata. In leaves, water with nutrients is extracted from soil by roots. Perspiration depends on the same factors as evaporation, to which plant characteristics (plant type, size, stage of development, applied technology, etc.) and water salinity are added, the latter retaining water in the tissues. In general, when plants are small evaporation prevails and when they are large and shade the soil, perspiration prevails (80-90%), the combined process being called evapotranspiration (ET).

Factors that affect evapotranspiration in Dobrudja. The intensity of evapotranspiration is expressed as atmospheric ETo (ETo), formerly known as *potential evapotranspiration* (ETP). Today, it is recommended that the latter term no longer be used, although it is still used under inertia. ETo was introduced to express the evaporative demand of the atmosphere independently of vegetation, its stage of development or management type. Water evaporation requires large amounts of energy, the process being governed by energy exchange at the surface of the vegetation as it is limited by the amount of energy available.

ETo is the evapotranspiration of a standard surface covered with grassy vegetation of low height (about 12 cm) with a constant resistance of 70 s / m and albedo of 0.23, which completely shades the soil, water being supplied with optimal moisture amount so that soil humidity should not affect the ETo size. The climatic factors are the only factors that influence the ETo.

Unlike ETo, defined above, ET depends on the type of vegetation (forest, grassland, orchards, cereals, etc.), phase of development and variety of plants, resistance to perspiration, roughness and plant albedo, height and root system of culture vegetation. In standardized conditions, the evapotranspiration of culture plants or of spontaneous vegetation (ET_c, or crop water requirement) refers to the evaporative demand of the atmosphere for plants grown on large areas with optimum water and environmental conditions and provided with a correct management. Restrictive environmental factors such as: high salinity or poor soil fertility, water pooling and lack of aeration of difficult soils, plant diseases, etc. may reduce the value of ETC. Water demand for irrigation is the difference between the culture water demand and actual rainfall.

There is a clear distinction between ETo and ETC. ETo is a climatic parameter indicating the evaporative demand of the atmosphere, while ETC is an agricultural parameter that shows the water consumption by vegetation, namely of crops or forests that are supplied with optimal conditions of humidity,

environment and management. For each time period (month) and crop, if ETo and the correction coefficient of culture (Kc) are known, with monthly values, Etc can be determined, as the following relationship exists between ETo (mm) and ETC (mm):

$$ETC = ETo \ Kc$$

where: Kc is a factor that depends on the type of crop and its development phase, ranging generally between 0.3 and 0.4 at the beginning of the growing season, culminating with a maximum water consumption month (mostly in July), when values of 1.2 can be encountered. Land improvement or irrigation deals with its study.

Methods for calculating the ETo. In conditions of high accuracy, ET determination can be made in special facilities called lysimeter, which are tanks made of metal, concrete or composite materials, with dimensions of several square meters, isolated and filled with soil under conditions similar to those in the field. Representative plants of the same size as the ones in the surrounding plot are then cultivated here. Water consumption is determined based on the equation of balance as the difference between water inputs (precipitation, irrigation) and its outputs (drainage). There are lysimeters with weighing and drainage system, or only with drainage system. When planted with grass and supplied with an optimal amount of water, the lysimeters determine ETo, while in the case of any other culture, they determine ETC.

Water evaporation from open water surfaces, which integrates the effect of global radiation, air temperature, air humidity and wind speed, is measured with evaporimeters (pan evaporation), the best known of which is the class A evaporimeter. These are cylindrical, metal tanks, with a diameter of approximately 1.2 m, in which the diurnal variation of water level due to evaporation is measured. ETo can be estimated by applying empirical coefficients for local calibration, using water evaporation from evaporimeters.

3. Thornthwaite aridity index (IAR-TH)

IAR-TH (%) was calculated according to the Thornthwaite method (1948), as percentage ratio between the sum of monthly climatic water deficit (precipitations minus ETo-PM, without taking into account the water excess in certain months of that period) and the sum of the monthly values of ETo-PM calculated for the vegetation period (April-October) in the first case, and with the help of ETo-TH in the second case. If the rainfall exceeded the ETo, the value of this index was considered invalid.

$$I_{ar-TH1} = 100 \ x \ \Sigma(P - ETo\text{-}PM) / \Sigma \ ET_oPM$$
$$I_{ar-TH2} = 100 \ x \ \Sigma(P - ETo\text{-}TH) / \Sigma \ ET_oTH$$

Dobrudja is characterized by a pronounced aridity (IAR-TH> 40) or even 60-65% in the eastern part of Danube Plain, signifying a very high aridity. Unlike IAR-DM (mm / ° C), IAR-TH (%) measures aridity as a percentage of ETo for the growing season, being thus more suggestive than the former. Thus, the use of I_{ar-TH} permits a more "realistic" framing of climate aridity in Dobrudja, the arid zones in this classification being closer to the climatic and agricultural findings.

4. Annual climatic water deficit

The difference between the annual values of precipitation and of ETo-PM is defined as the annual climate deficit (DEF) of water, with a negative mark. Unlike IAR-DM, re is a relationship between precipitation and temperature (with a conventional addition of 10° C to yield positive values). DEF is the difference between the more appropriate terms that characterize the essence of natural landscape, by the contribution of ETo instead of temperature, as precipitation and ETo have the same measurement units, mm. Compared with the IAR-TH, DEF displays absolute values (mm), and not relative values, percentage of ETo.

According to the DEF values, the most arid region of the country is the Black Sea coast, where values of approximately -400 mm and even -350 mm are recorded, Figure 3. The annual DEF-400 mm isoline crosses eastern Danube Delta. In contrast, the western part of the Dobrudja Plateau is characterized by an annual DEF between -300 to -400 mm, this region being ranked second in regards to the intensity of aridity. Unlike the indicators that characterize drought (SPI) or the other indicators that characterize aridity, the DEF indicator has the advantage of the precise quantification of the average water demand for the reference culture (grass) in different regions of the country or anywhere in the world. Using the correction coefficients of agricultural crops, this indicator provides information regarding the standard monthly irrigation or during the growing season. Therefore, for practical reasons, the DEF indicator fits best because it is closely related to the amount of water applied by irrigation.
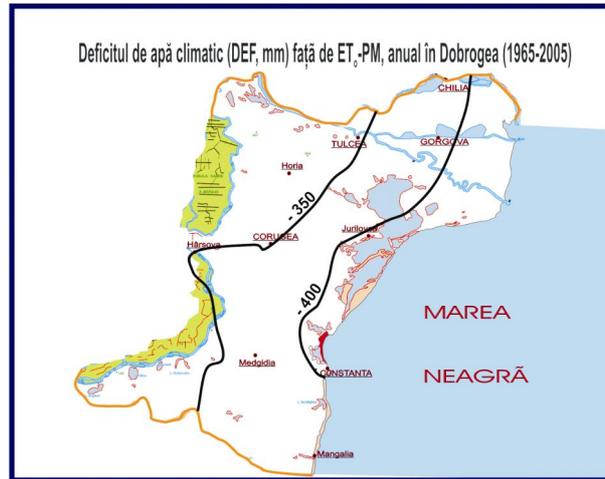
Fig. 3. Annual climatic water deficit in Dobrudja (DEF,mm) compared to ET,PM, (1965-2005)

5. The UNESCO aridity index 1979, as ratio between precipitation and ETo-PM. Another aridity index, called UNESCO 1979, Iar-P/ETo, is defined by the ratio (P / ETo, annual values, mm / mm), which is widely used today, based on the calculation of ETo ETo-PM in this paper, although initially it was based on ETo-Penman (UNESCO, 1979). According to this aridity index, the climate classification is described in table 2. Danube Delta corresponds mostly to the mildly-wet class (Iar-P/ETo = 0.5 to 0.55), whereas the eastern Danube Delta and the Black Sea coast fit within the semiarid class (Iar-P/ETo = 0, 2 to 0.5), figure 4.

Table 2. Climatic aridity classes according to Iar-P/ETo (UNESCO, 1979)

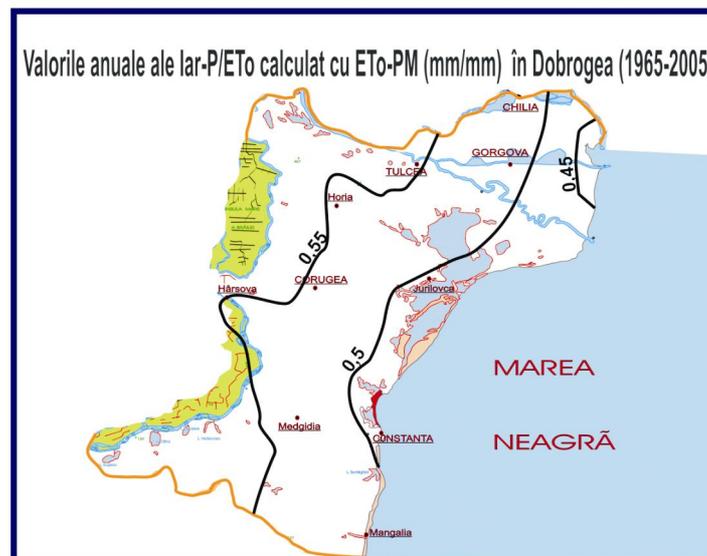| Value of $I_{ar} = P/ET_o$	Climate Class
≤0.03	Hyper-arid
0.03-0.20	Arid
0.20-0.50	Semi-arid
0.50-0.65	Dry mildly-wet
> 0.65	wet

Fig.3. Annual values of I_{ar} –P/ET_O calculated with ET_O-PM (mm/mm) in Dobrudja (1965-2005)

CONCLUSIONS

Danube Delta aridity is highlighted by all climatic aridity indices presented above. It can be addressed with additional indicators. Increasing aridity in Danube Delta due to global warming is a real

hazard, with the threat of desertification. The impact of climatic changes and the significant negative effects incurred on the main components of water balance and on maize production are estimated based on the CROPWAT model (Smith, 1992) and scenarios derived from the climate model HadCM3. In this respect, the availability of water for crops will decrease due to the association of greater daily ETo values with a higher deficit of soil moisture and decrease of the amount of rainfall. For example, the average monthly temperature will increase by approximately 2.5º C in August in 2020 and by approximately 4.8ºC during 2050, when ETo will rise up to 8-16% over the same period while the irrigation water demand will increase by approximately 15-28%. According to this scenario, a decrease of soil moisture will lead to a reduction of the real maximum evapotranspiration of the crop by 16 to 24% by the years 2020-2050, despite an increased evaporative demand of the atmosphere.

The Romanian Government and local authorities should develop appropriate policies for the regions affected, such as rehabilitation of irrigation systems using a strategic plan for all aspects of water requirements and application of a rational use of water resources based on risk management and not crisis management.

Another strategic direction is to use the proper agricultural and horticultural species, the cultivars and hybrids with maximum resistance to water stress, especially in the southern regions of the country. Otherwise, the maize production for example, could be reduced to 60-70% due to water stress over the following decades because of very high temperatures that would shorten the vegetation period associated with the water stress during the seed filling phase.

In conclusion, as we remarked in the previous section, there is a clear difference in content between drought and aridity, although sometimes they are confused in common expression. Aridity is a permanent feature of a region characterized by low average rainfall, while drought is a temporary feature of any region. This idea must be supplemented by the indication that the low rainfall amount in arid regions is associated with intense evapotranspiration. Otherwise, the precipitations could accumulate like in the polar regions with snow accumulation.

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